

DMSO Workshop on Composable M&S

7-9-2002

Two Aspects of Composability: Lexicon and Theory

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Presentation outline

- Composability lexicon
- Towards a theory of composability
- Conclusions and references

Composability lexicon

Same word, different meanings

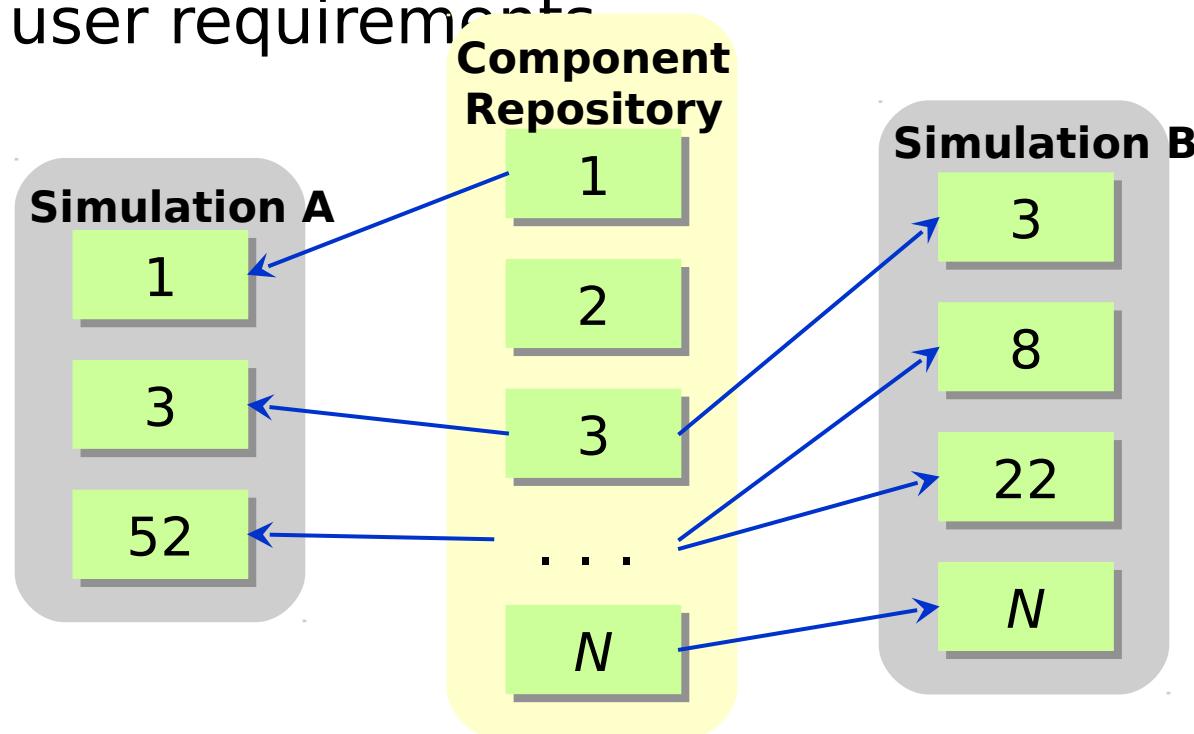
- Different meanings for “composability”
 - Occurs in both documents and discussion
 - Noted previously [Page, 1998]
 - Found in review of composability literature [Petty, 2002]
 - Experienced at composability meeting

The ability to rapidly configure, initialize, and test an exercise by logically assembling a simulation from a pool of reusable components [JSIMS, 1997].

The ability to create, configure, initialize, test, and validate an exercise by logically assembling a unique simulation execution from a pool of reusable system components in order to meet a specific set of objectives [Harkrider, 1999].

Proposed common definition

Composability is the capability to select and assemble simulation components in various combinations into simulation systems to satisfy specific user requirements.



Levels of composability

- Different meanings often differ in “level”
 - Level determined by component and composition

Components	Composition	Example
Applications	Events	Unified Endeavor
Federates	Federations	Joint Training Confederation
Packages	Simulations	JSIMS
Parameters	Simulations	JSIMS
Modules	Executables	OneSAF
Models	Composite models	OneSAF
Data	Databases	SEDRIS
Entities	Military units	WARSIM
Behaviors	Composite behaviors	ModSAF

- Application level
 - Applications composed into events
 - Applications: simulations, C4I systems, networks, communications systems, auxiliary software
 - aka “event” level [Post, 2002]
- Federate level
 - Federates composed into federations
 - Persistent federations, federates may change
 - aka “federation” level [Post, 2002]
- Package level
 - Packages composed into simulations [JSIMS, 1997]
 - Packages: sets of models forming consistent subset

- Parameter level
 - Parameters used to configure existing simulations
 - aka “simulation” level [JSIMS, 1997]
- Module level
 - Software modules composed into executables
 - Result may be federate or standalone simulation
 - Example: OneSAF [U.S. Army, 1998] [Courtemanche, 2002]
- Model level
 - Models composed into composite models
 - Example: sub-systems composed into entities
 - Example: OneSAF [Henderson, 2002]
 - aka “object” level [Post, 2002], “component” level

- Data level
 - Data sets composed into databases
 - Example: SEDRIS
- Entity level
 - Platforms/entities composed into military units
 - May be hierarchical, multi-leveled
 - aka “federate” level [Post, 2002]
- Behavior level
 - Behaviors composed into composite behaviors
 - Behaviors executed autonomously, e.g., CGF systems
 - Examples: FSMs [Calder, 1993], flow diagrams [Peters, 2002]

Composability and interoperability

Interoperability is the ability of different simulations, connected in a distributed simulation, to meaningfully collaborate to simulate a common scenario or virtual world.

- Composability = interoperability?

No.

- Interoperability is **necessary** but **not sufficient** for composability
 - Composability requires interoperability
 - Interoperability possible without composability, i.e., without ability to combine and recombine, reuse
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- Example: Platform Proto-Federation [Harkrider,

Two types of composability

- Engineering composability
 - aka “syntactic” composability [Pratt, 1999] [Ceranowicz, 2002]
 - Ability to integrate composable components; APIs, parameter passing, data access, timing, ...
- Modeling composability
 - aka “semantic” composability [Pratt, 1999] [Ceranowicz, 2002]
 - Ability of composed models to meaningfully represent object; data content, assumptions, ...
- Analogous interoperability types
 - Engineering composability ~ technical interoperability

Towards a theory of composability

Introduction

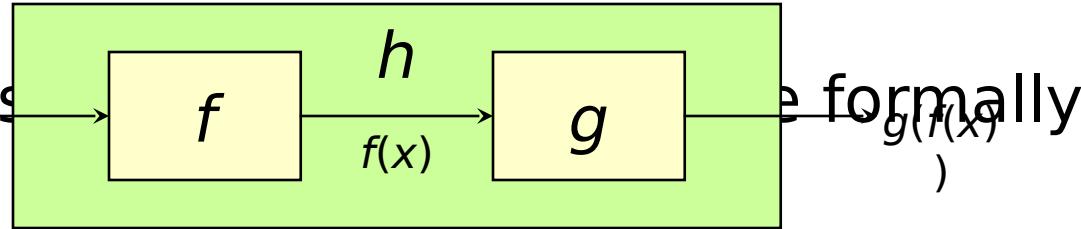
- Much work on engineering composability
 - Dynamically loadable **modules** [Franceschini, 1999]
 - Autonomous **behaviors** [von der Lippe, 2002] [Peters, 2002]
 - OneSAF **models** [Henderson, 2002]
- Seek to address modeling composability
 - Develop and apply formal theory of composability
 - Some previous work [Overstreet, 1982] [Page, 1999]
- Project getting started
 - Dissertation, ODU M&S Ph.D. program
 - Eric W. Weisel

Models

- Models are basis for the theory
- Official definition
 - *Model*: A physical, mathematical, or otherwise logical representation of a system, entity, phenomenon, or process [DOD, 1996] [DOD, 1998]
 - Assumption of validity?
- Formal definition for composability theory
 - *Model*: A computable function
 - *Function*: Relates each input to unique output
 - *Computable*: Calculable by finite procedure

Linking model semantics, formal theory

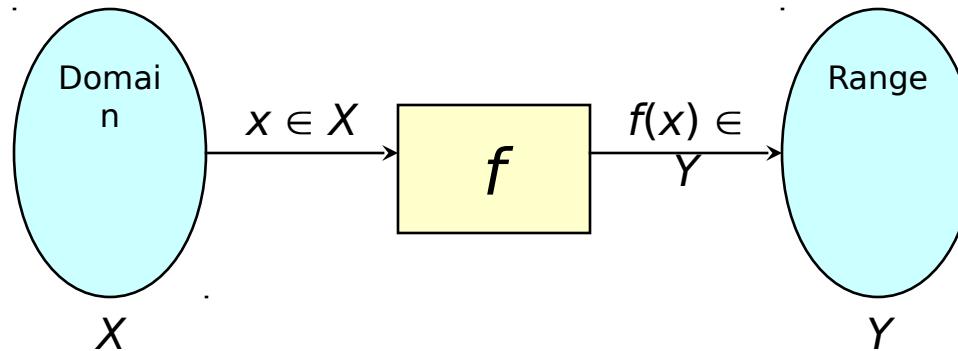
- **Validity** links semantics and theory
 - Model semantics are established as validity
 - Models may or may not be valid
 - Is validity preserved when composing valid models?
 - That question can be formally



- Suppose models $f(x)$ and $g(x)$ are valid
- Is composite model $h(x) = g(f(x))$ valid?
- For what inputs x is composite model $h(x)$ valid?

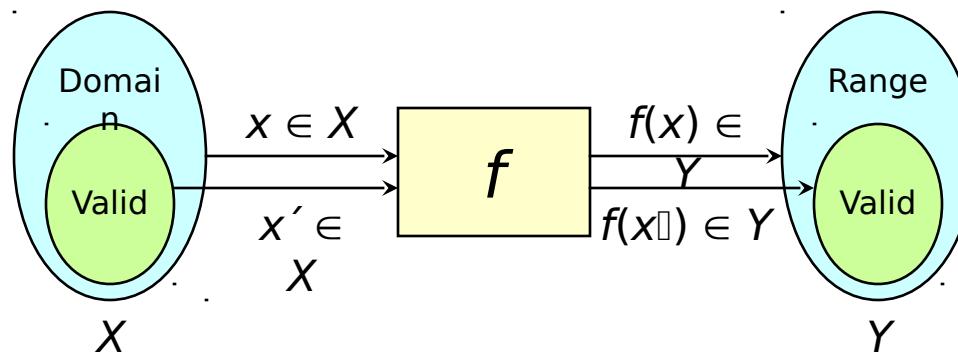
Validity of composite models

- When is a composite model valid?
- Functions
 - Map domain (input) to range (output)
 - Exactly one output for any given input



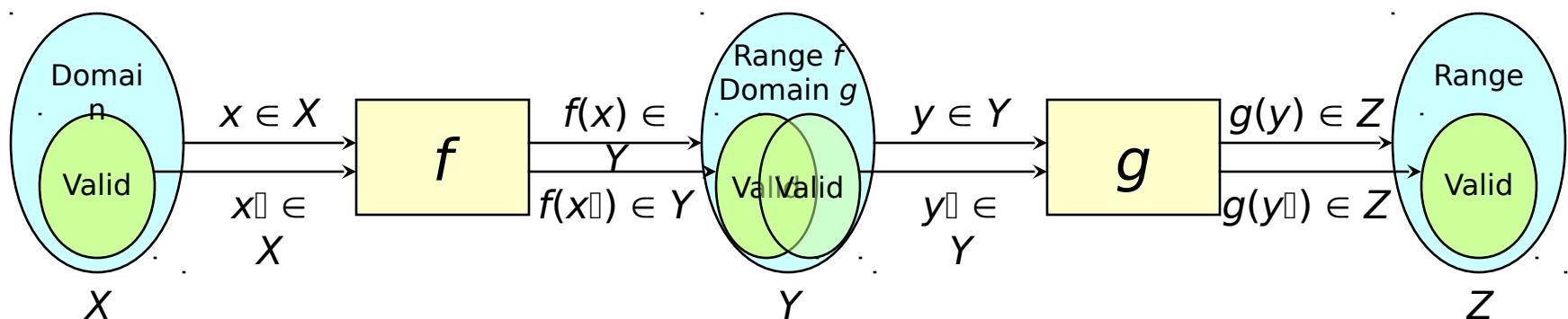
$$y = f(x)$$

- Validity and models as functions
 - Model valid for a subset of its domain
 - Model result valid in a subset of its range
 - Valid output produced from valid input



$$y = f(x)$$

- What is a composite model?
 - Models are functions
 - Composite models are composite functions
- When is a composite model valid?
 - When valid ranges and domains intersect



$$z = g(f(x))$$

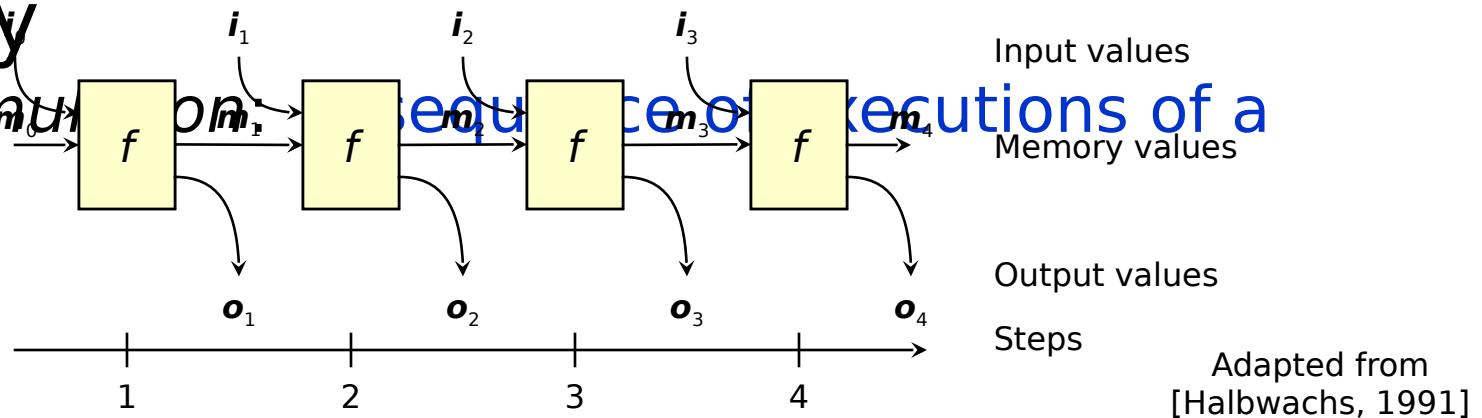
Validity

- How is validity determined initially?
- Option 1: meta-property of models
 - Determined **outside** formal system by validation
 - “Model f is valid for inputs $X' \subseteq X$ ”
- Option 2: formal property of models
 - Branch of mathematical logic: “model theory”
 - Relations between sentences in formal language, interpretations which make them true [Hodges, 2000]
 - Describe model and real-world axiomatically, establish validity **inside** formal system
- Then preserve validity in

Simulation

- What is a simulation?
- Official definition
 - *Simulation*: A method for implementing a model over time [DOD, 1996] [DOD, 1998]
- Formal definition for composability theory

- *Simulation* sequenced executions of a model



Objectives

- Questions that may be resolved formally
 - Can the validity of a composition be checked algorithmically, given the validity of its components?
 - If yes, what is the algorithm, and what is its computational complexity?
 - What conditions must be met to preserve validity in a composition?
 - Can validity be established formally with model theory?
 - Are existing simulation formalisms (e.g., DEVS) equivalent to computable functions?

Conclusions and references

Conclusions

- Lexicon
 - Composability has several related meanings
 - Differences often depend on **level**, unit of composition
 - Common notions: interoperable, reusable, and recombinable components
- Theory
 - Modeling composability can be approached formally
 - **Validity** is link between semantics and theory
 - Computability theory and model theory are tools

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